450 Golden Gate Project

BACnet's™ First Large-Scale Test

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The energy management system (EMS) industry has advanced rapidly over the past 10 to 15 years. Today, EMS technology provides building owners and designers with incredible design and operational flexibility. State-of-the-art EMS systems are characterized by powerful PC workstations and intelligent field panels that process complex control algorithms quickly and efficiently.

In spite of these advances, building owners have been frustrated by the inability to bid projects competitively and to integrate innovative products from different manufacturers in ways that best suit the unique needs of their facility. The adoption of BACnet™[1] as the standard protocol for integrating building control products has forever changed the industry and opened the door to new innovation in building control technology.

Today, thousands of BACnet systems are installed and can be found in at least fourteen countries.[2] Many of these are small-scale projects where BACnet was used to integrate new HVAC equipment with an existing proprietary building automation system. Others are complete BACnet systems that use products from only a single vendor. The 450 Golden Gate Project is unique because of its large size, the involvement of multiple vendors and the inclusion of more than just HVAC control. This project will significantly impact the way the largest landlord in the world—the U.S. General Services Administration (GSA)—will manage its buildings in the future.

This article provides an overview of the project design, the demonstration team's experiences to date and recommendations for engineers and building owners considering BACnet in their future automation projects.

Background

The GSA owns and operates most buildings used by the civilian branches of the federal government. This amounts to about 8% of all office space in the United States. GSA is committed to improving the safety and comfort of the building occupants while simultaneously reducing energy and operating costs. Modern building control technology is a key tool for achieving these goals. As a government agency, open and competitive procurement is also a prime concern. Thus, GSA became interested in BACnet because it provides the common communication infrastructure necessary to achieve these goals.

In 1996, the Phillip Burton Federal Building and U.S. Courthouse located at 450 Golden Gate Avenue in San Francisco was selected as the site for the first large-scale commercial demonstration of the BACnet standard. The site, a 22-story 130,000 m^2 (1.4 million ft^2) office building, is the second largest office building in San Francisco and the largest federal office building west of the Mississippi River. It was selected for this demonstration, in part, because it had few pre-existing EMS controls and recent renovations have made it comparable to typical commercial office buildings.

The EMS retrofit also represented a significant energy efficiency opportunity for the building with projected annual utility savings of over $500,000. The project tests multiple EMS-manufacturers' equipment in one facility and their ability to cooperatively monitor and control building systems by utilizing the BACnet standard. In addition, extensive energy monitoring instrumentation, an operator workstation network, and communications equipment were incorporated into the EMS design to facilitate future energy assessment and research activity within the building.

Contract awards for the first two BACnet compliant vendors were made in August 1996. Associated construction activities were completed in January 1998, and the project remained on schedule and on budget. Follow-up phases of work will include BACnet-based gateways to an existing lighting control system installed on the building's GSA floors, a pre-BACnet EMS in-

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Operator Workstations Network

One of the most unique aspects of this project involves the operator workstation environment. Due to the multi-vendor configuration, ensuring effective operator training and a consistent operator interface were major concerns for GSA. To optimize operator efficiency and provide a uniform interface to the EMS, one vendor's workstation software (as per Scope F) was selected as the basis for common Operator Workstation Network (OWN) access.

All other EMS vendors were responsible for coordinating with the workstation vendor to ensure that consistent color graphics, data presentation and control parameters were established for all systems. *Figure 1* illustrates a simplified view of the OWN configuration.

Subsequent to award, and as each individual vendor's system was tested and accepted, the Scope F vendor was required to integrate every other vendor's EMS installation into its BACnet-compatible workstation software.

Once completed, this single workstation package became the primary multi-vendor access tool for the entire building. The result is a common and consistent method of presentation and access to all EMS information from any workstation, regardless of which vendor's EMS is examined.

A primary design issue for the workstations and the OWN was the database organization and distribution. The 450 Golden Gate EMS is a large and complex system. The resulting network needs to maintain a consistent and up-to-date EMS database (including controller configuration, programming, trending, color operator graphics, etc.) for the complete EMS installation. This is accomplished by storing EMS data on the OWN file server, thus supporting a centralized repository for trend data, third party and vendor-specific application software and future research.

The file server also regulates communications among workstations on the OWN as well as shared resources such as files and printers. In addition to LAN management, the file server hosts the archiving and back-up services for the OWN.

The OWN/EMS configuration also provides remote operator access to the EMS and automatic remote alarm reporting via telephone connections using the BACnet Point-To-Point (PTP) protocol. This dial-up access to the EMS provides the same interface and functionality as the directly connected workstations.

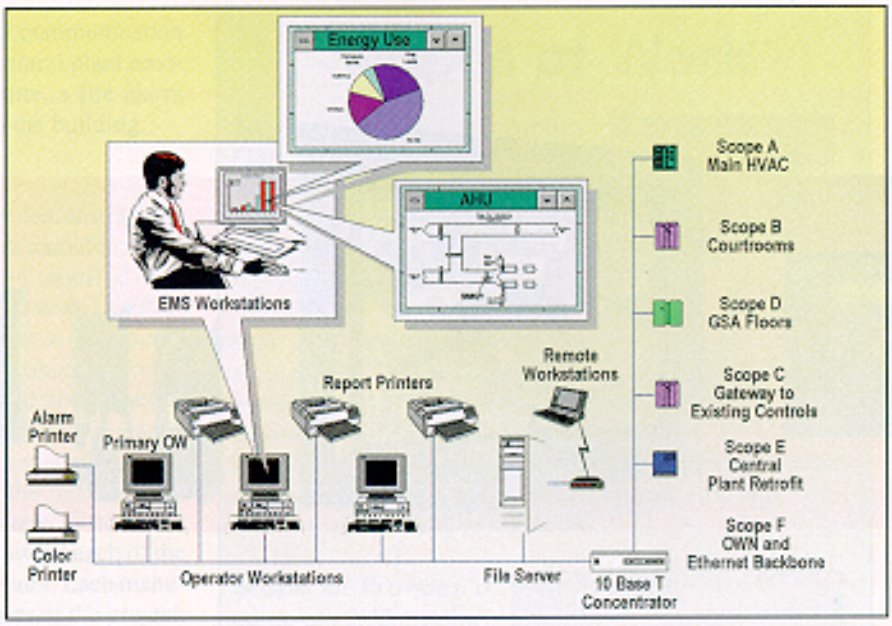

Figure 1: EMS Schematic. With all critical zone level information exchanged using BACnet messages, building operators can view HVAC information from multiple vendors' systems through a common color graphic interface.

Utility End-Use Monitoring

The EMS design included extensive utility monitoring instrumentation to provide access for GSA and the local utility to building energy information for each primary end-use category (e.g., space cooling and heating, domestic hot water, ventilation, lighting, vertical transportation, plug loads).

Instrumentation was provided for monitoring of both site energy consumption (e.g., electricity and natural gas) and delivered thermal energy (e.g., cooling and heating Btus). This data is available in real-time and stored for historical record.

Conventional EMS sensors are used in conjunction with more specialized end-use instrumentation to provide a cost-effective monitoring design. For example, current switches and other status indications used by the EMS for start/stop "proof" of constant load devices (pumps, fans, etc.) are also used to track power consumption of these same loads.

This is accomplished by defining pseudo (software) points based on "spot" kW measurements of the loads during system installation. These individual software points are then summed by end-use category into totaled values within the EMS.

Vendor Procurement Process

The procurement process for the 450 Golden Gate project began shortly after ASHRAE's release of the BACnet standard in late 1995. The first step involved a detailed Request for Qualifications (RFQ) in which information was requested on numerous vendor's product lines, current and future plans for incorporation of BACnet communications, operator workstation environment, as well as more traditional information on local resources and federal building experience.

This review process led to the release of a more rigorous Request for Proposal (RFP) to six vendors in early 1996. Because the RFP release occurred shortly after ANSI adopted BACnet, the project team was aware that the 450 Golden Gate project was going to be an early test of the "BACnet marketplace."

It takes companies several years to develop a new product line. At the time proposals were solicited for this project there was a concern that there may not be a competitive bidding environment. Therefore, specifications indicated that BACnet communication was mandatory only for workstations and primary field panels.

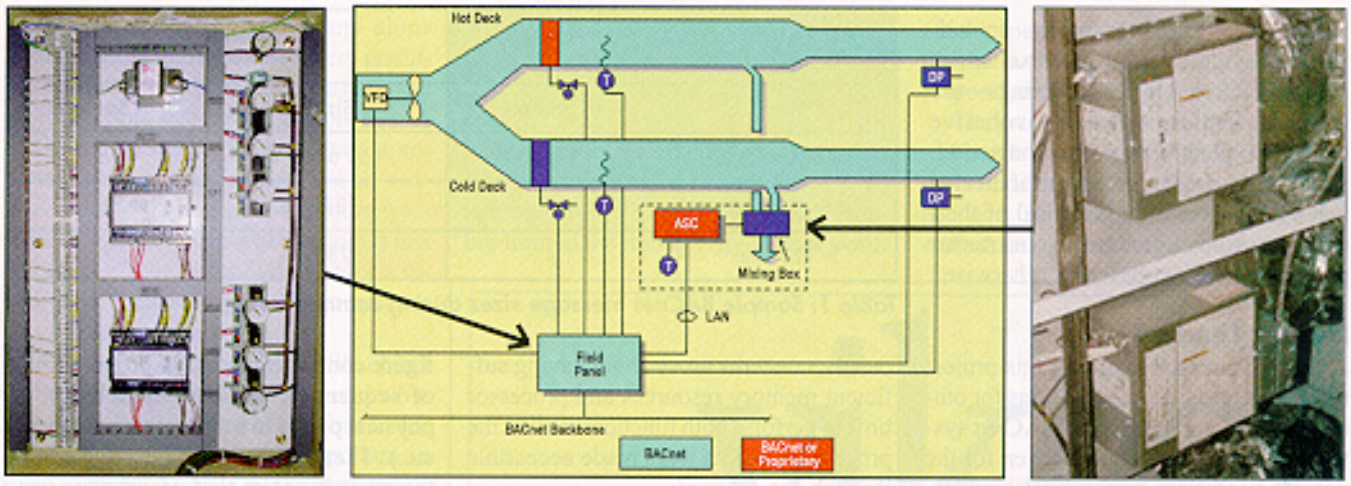

Figure 2: Example EMS controller distribution for a dual-duct air-handler system. The retrofit included DDC conversion of nearly 1200 VAV boxes of which both BACnet and non-BACnet speaking controllers were installed. Zone information from the non-BACnet controllers is translated to BACnet messages by supervising field controllers.

For communication between field panels and unitary controllers, proprietary communication options were acceptable. This could include a primary control panel serving as a BACnet gateway. Various vendors proposed both all-BACnet and mixed-protocol designs.

An evaluation committee comprised of representatives from GSA, the local utility, the engineering design firm and NIST reviewed all vendor information submitted. The committee selected two vendors for the project. Scopes A, B, and F were awarded to one vendor and Scope D was awarded to another vendor. Funding was not yet in hand for the central plant retrofit defined in Scope E and no acceptable solution to integrating the existing control systems of Scope C was available at the time of the bid.

However, the work of Scopes C and E will be incorporated into a design package for a 1998–99 construction phase. Thus, once the subsequent "C and E Scopes" are completed, the entire EMS will be comprised of control products from up to five different vendors.

Of the two vendors selected for the current construction phase, one system utilizes proprietary communications at the unitary controller level (such as VAV box controllers) with primary field panels serving as both controllers and gateways communicating via BACnet over the system's Ethernet backbone. The other system uses BACnet communication exclusively.

BACnet Myths Dispelled

Many lessons have been learned from the 450 Golden Gate project. In successfully demonstrating BACnet communications within a large-scale project, some street mythology about BACnet has been disproved. Consider four pearls of conventional wisdom about BACnet in light of actual project experience.

Myth 1: BACnet is not real, or at least not ready. It is true that it takes time for companies to develop new BACnet products. In general, it is more difficult for large companies to change quickly. It is also true that companies are still developing their BACnet product line. However, BACnet products are currently available from multiple companies.

It is possible to find vendors who can meet stringent BACnet specification requirements even for a project the size of 450 Golden Gate. In some cases participating vendors modified their product enhancement schedule to accommodate the project's requirements, but all of the installed products are currently available in the marketplace.

Myth 2: BACnet is too complicated and expensive for low-level controllers. No evidence from this project exists that BACnet products cost more than comparable proprietary products. Over 1,000 BACnet unitary controllers are operating in this system. Through a competitive bid process, no cost premium was paid at any level for using BACnet.

Myth 3: BACnet messages are too big and inefficient. This may be the only EMS installation that has been instrumented to examine issues such as network traffic patterns and message size distribution. The data collected includes continuous sampling of backbone traffic during even the heaviest traffic periods of system testing and configuration. Under these conditions, active workstation use and extensive trending were employed to verify correct system operation. *Table 1* summarizes the data from two such samples. The first sample consisted of about 46 million messages collected over 30 days and the second sample consisted of 62 million messages collected over 41 days.

Almost all of the messages are exactly 60 bytes long. Ethernet requires messages to be at least 60 bytes long in order to detect collisions. The fact that these messages are exactly 60 bytes long means that they have been padded to make them large enough to transmit over the Ethernet LAN. This implies that BACnet messaging is so efficient that most messages are less than 60 bytes. This data contradicts claims that BACnet was optimized for large systems and is not practical for small devices.

Myth 4: Cooperation between vendors to solve problems will never happen. As with any large-scale construction project, some issues arose while the system was being installed and commissioned. Partially configured controllers and missing or misunderstood information caused a few glitches along the way. However, there was never any difficulty isolating the cause of a problem, defining its remedy and assigning responsibilities among the vendors.

Because of careful planning—including inter-vendor submittal exchanges and productive progress meetings—the multiple vendors acted as a cohesive team throughout the construction period. In fact, the project's vendors indicated that such cooperation is typical of their other multi-vendor/multi-contractor projects—BACnet-based or otherwise.

Sample 1 (46 million messages)		Sample 2 (62 million messages)	
Size	% of Sample	Size	% of Sample
60 bytes	85.4	60 bytes	93.5
61–128 bytes	13.2	61–128 bytes	2.6
> 128 bytes	1.4	> 128 bytes	3.8

Table 1: Sample BACnet message sizes during commissioning.

Lessons Learned

Some issues arose during this project that are important considerations for others designing or specifying BACnet systems. One of the vendors chosen for the project uses field panels that simultaneously act as a controller, as well as a gateway to the vendor's unitary (non-BACnet speaking) controllers. The project specification indicated exactly what information must be accessible through the gateway (an important point for specifying engineers). However, when the time came to configure those field panels, concerns arose about having sufficient memory resources and processor time to perform both functions if all of the proprietary points were made accessible through the gateway.

In the end some compromises were made to achieve a workable solution. Any system that has a gateway can experience this kind of problem—especially when an expansion takes place. Although gateways are sometimes necessary, they always come at a price.

BACnet does not define how to configure controllers (such as programming of sequences, addition or deletion of physical points to a controller's database, etc.). Therefore, it was understood from the project's start that proprietary vendor-specific tools would be needed to configure the installed systems. The intent of the specifications was to install "stand-alone" versions of these configuration tools on the network file server, thus permitting access to these vendor-specific applications from any workstation.

Unfortunately, this did not prove to

be possible. Even though stand-alone configuration tools would be very practical from the perspective of the user, most EMS vendors bundle these tools as part of their workstation software as a complete package. And, because not all vendors support the same PC operating systems, a separate PC may be required just for the configuration of one vendor's installation. Pressure from users may cause this to change over time.

Although BACnet defines a file object and application services to read and write files, it does not define a file format for trend logging. Trending is important in most systems. At 450 Golden Gate trending was extremely important because of the need to collect data for the research aspects of the project. To make this work in a multi-vendor environment it was necessary to specify exact details of how trend data was to be collected and what file formats would be used for archive functions.

The final methodology employed for trending is being reviewed by ASHRAE Standing Standard Project Committee (SSPC) 135, BACnet—A Data Communication Protocol for Building Automation and Control Networks, and may be incorporated into the standard.

Finally, no industry certification program exists for BACnet products at this time. Finalization of specific testing procedures is a high priority of SSPC 135 and many are working toward a formal certification process. Fortunately, GSA was able to turn to the National Institute of Standards and Technology (NIST)—one of the key players in the efforts to develop BACnet testing tools and procedures—for assistance in verifying that products on this job correctly implement BACnet protocols. This assistance is not generally available.

Companies in the industry have been working together to test products. Until a certification program is in place, it would be wise for consumers to request evidence that a company has done thorough testing and has some kind of field experience in multi-vendor environments.

Conclusion

The BACnet implementation at 450 Golden Gate has been overwhelmingly successful. The project's timing pushed the envelope of the controls industry and the marketplace. Within less than a year from ASHRAE/ANSI adoption of BACnet, a competitive procurement process was launched to demonstrate the viability of the technology and assess the EMS industry's acceptance of interoperability. Though the project's timing limited the number of vendors available to participate, nearly every major player in the industry enthusiastically responded to the initial RFQ.

The project proves that BACnet works as intended. In a real building and under real-world construction conditions, EMS products of multiple vendors were installed, networked over a single Ethernet

backbone and configured as part of a network of workstations running a common operator interface package. The result is a fully integrated building-wide EMS comprised of multiple manufacturers systems, but operating as a single system in terms of an operator's daily interaction with the entire EMS.

The cooperative spirit among the vendors led to a valuable exchange of information and continued evolution and improvement of respective product lines. This in turn has strengthened the understanding of the BACnet standard among project participants, as well as the industry at large. Continued penetration of BACnet into the marketplace is inevitable. The remaining challenges are educating owners about the benefits of interoperability, improving the understanding of EMS and BACnet technology among the design community, and an eventual "re-tooling" of the controls contracting industry for delivery of truly integrated building automation solutions.

Disclaimer

BACnet is a registered trademark of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. Ethernet is a registered trademark of Digital Equipment Corporation, Intel and Xerox, and is the basis for international standard ISO 8803-3. This version is used in BACnet systems.

References

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2. Bushby, S. T. Personal communication with representatives of the 21 members of the NIST BACnet Interoperability Testing Consortium.

3. Bushby, S. T. 1998. "Communication Gateways: Friend or Foe?" *ASHRAE Journal* 40 (4):50–53. ■

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